April 1, 1941. R. L. CAMPBELL 2,236,705

COMPOSITE SIGNAL DEVICE

Filed June 17, 1935 5 Sheets-Sheet 1

Fig. 1.

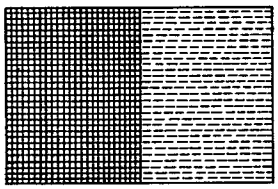

Fig. 3.

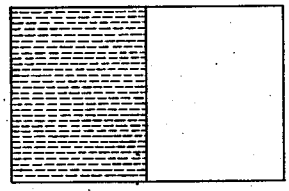

Fig. 2.

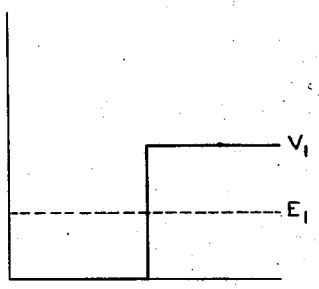

Fig. 4.

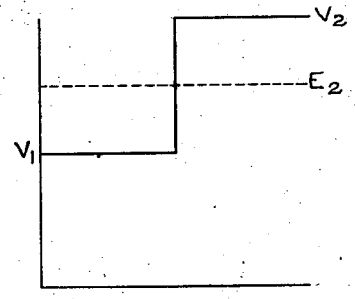

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Fig. 5.

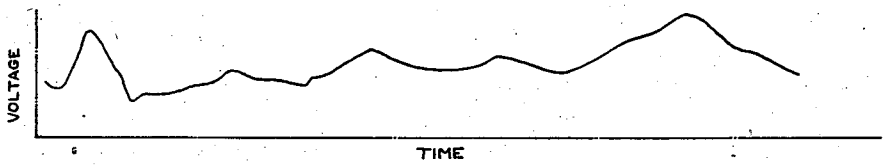


Fig. 6.

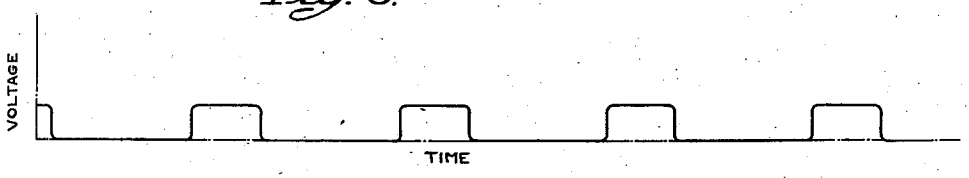


Fig. 7.

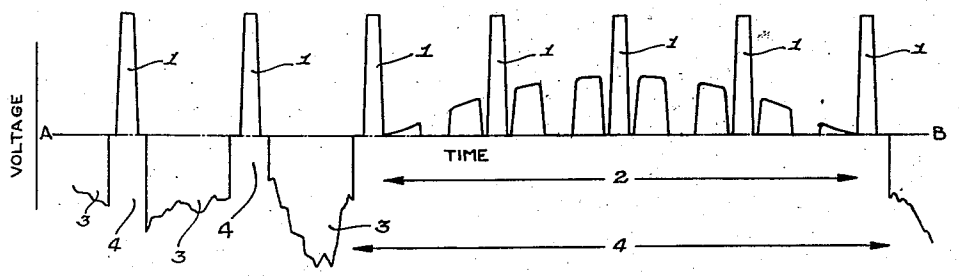
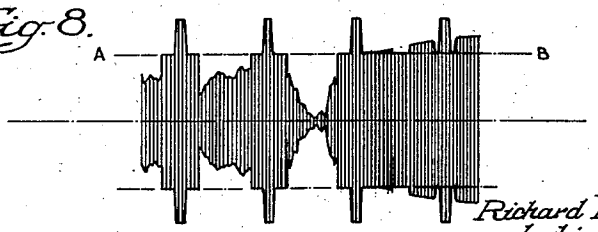


Fig. 8.



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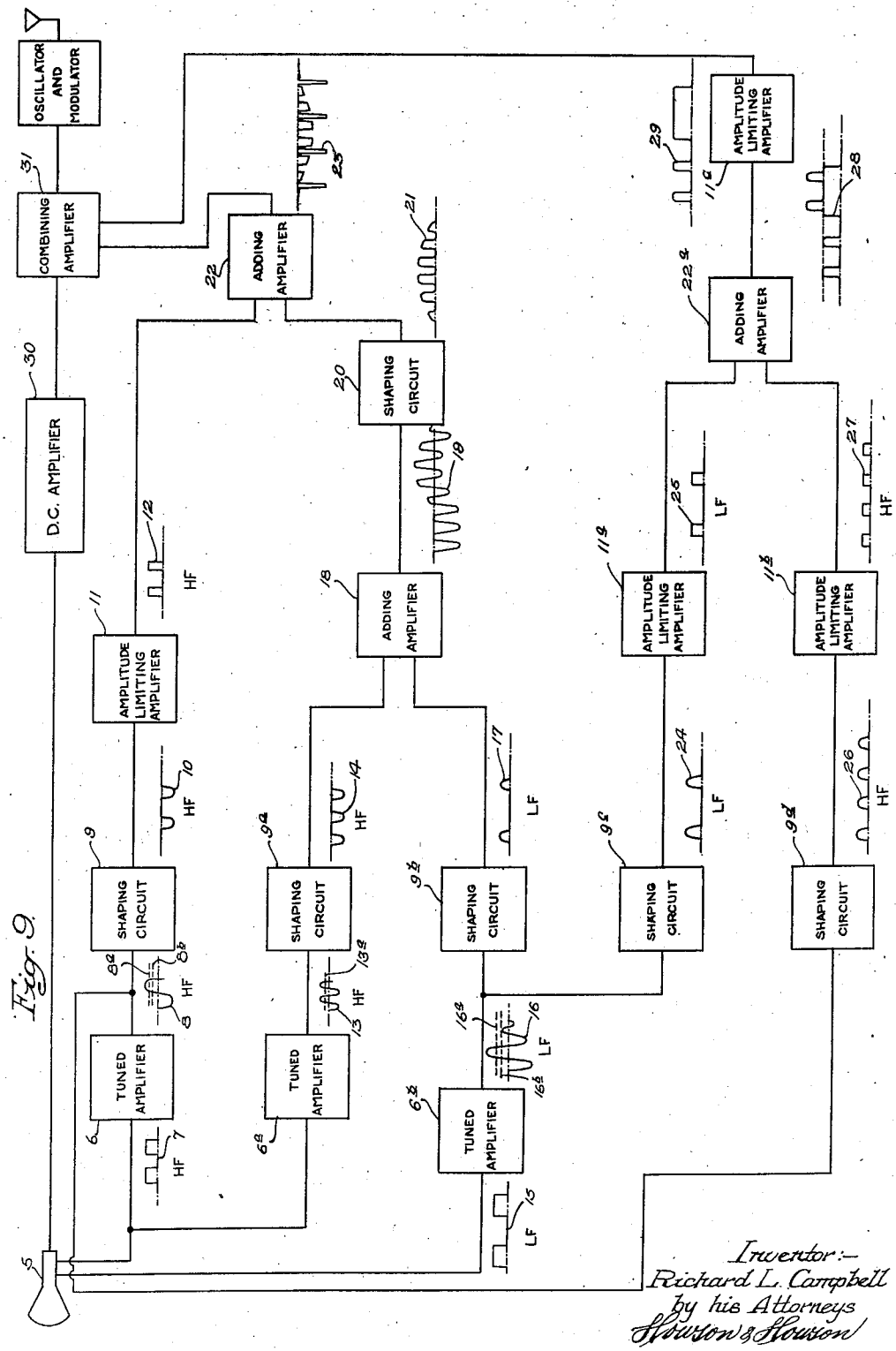

Fig. 9

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Fig. 10.

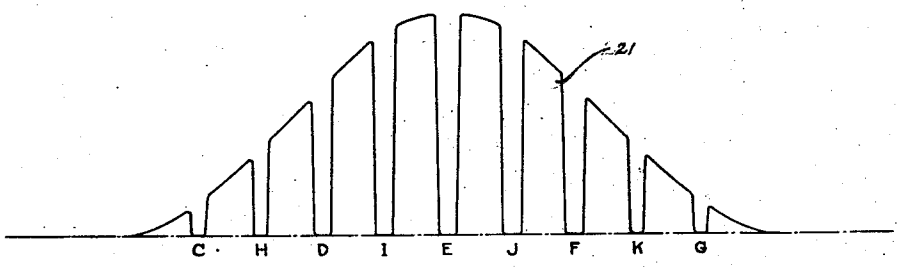

Fig. 11.

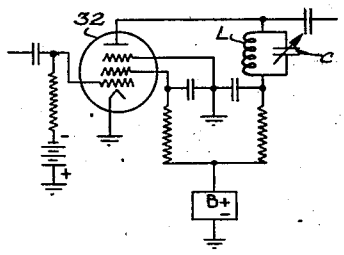

Fig. 12.

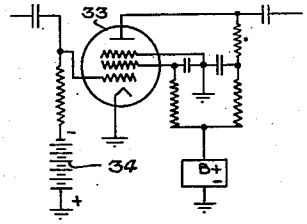

Fig. 13.

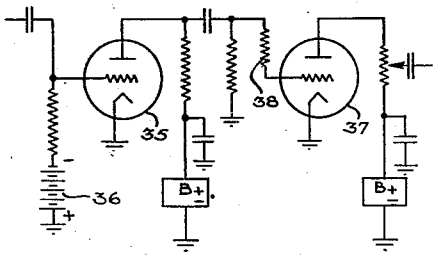

Fig. 14.

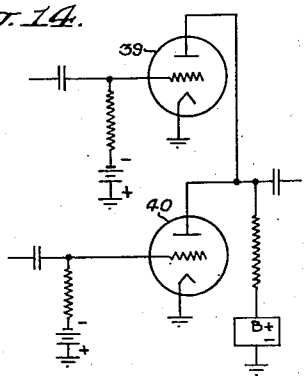

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Fig. 15.

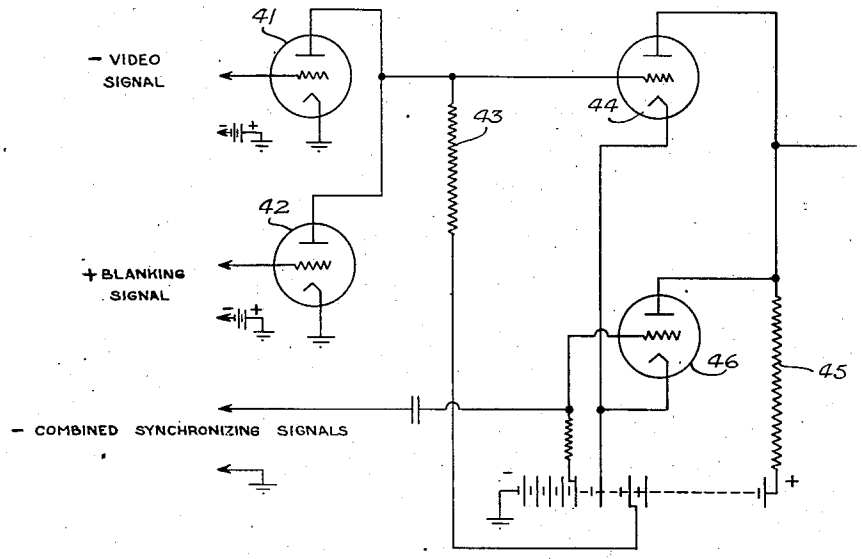


Fig. 16.

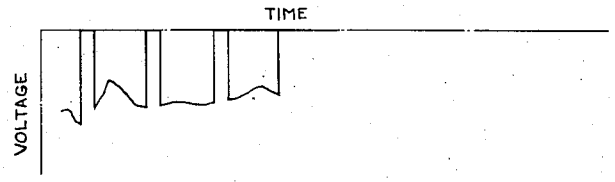


Fig. 17.

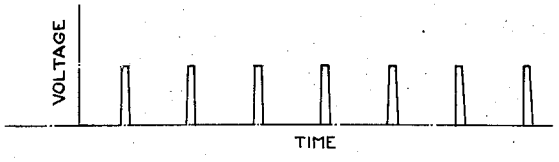
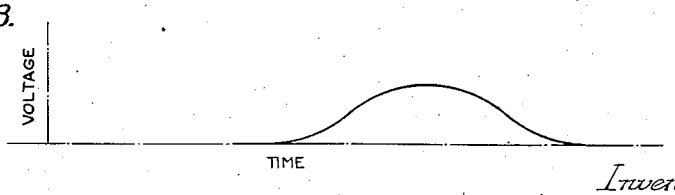


Fig. 18.



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Patented Apr. 1, 1941 2,236,705

UNITED STATES PATENT OFFICE

2,236,705

COMPOSITE SIGNAL DEVICE

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Application June 17, 1935, Serial No. 27,074

23 Claims. (Cl. 178—6)

This invention relates to an improved composite signal system, wherein two or more different signals may be combined in such manner that they may be readily separated later one from another without impairing their effectiveness, and wherein the signals are combined and maintained in predetermined relation to an established reference. The invention is very well adapted for use in picture transmission or television systems, and for the purpose of illustration and disclosure, it will be described in reference to this specific application, although it is to be understood that the invention is not thus limited but is capable of being practiced in any instance where the principles and features of the invention may apply.

In a system which is adapted to transmit visual images, as in the conventional television system, three or more different signals are usually combined, transmitted, and then separated before the individual signals are used. These three signals may be, first, the video or picture signal, second, a signal for synchronizing the horizontal scanning means, and, third, a signal for synchronizing the vertical scanning means. By the use of the present invention, it is possible to combine these various signals to form a composite signal which may be readily transmitted and in which the constituent signals are arranged in a certain manner and in proper relation to an established reference, whereby the signals may be separated readily at the receiving end of the system and the brightness of the transmitted picture may be accurately maintained or controlled, as will appear more clearly hereinafter. In some circumstances, only one synchronizing signal, rather than two, may be necessary and the invention includes features which may be used in such circumstances.

One object of the invention, therefore, is to provide a novel method and means whereby a plurality of signals may be combined in such manner and may be maintained in such relation to an established reference, that the signals may be readily separated and used individually at the receiving station, and a characteristic of the composite signal may indicate some medium or condition at the transmitting station and may accordingly be employed for control purposes at the receiving station, for example to control the brightness of the transmitted picture in a television system.

Another object of the invention is to provide in a visual image transmission system a novel method and means whereby the video signal may be combined with the synchronizing signals to produce a composite signal suitable for operating the signal receiver, and from which composite signal the component signals may be readily derived at the receiver.

A further object of the invention is to provide in a visual transmission system a novel method and means whereby the horizontal and vertical synchronizing signals may be combined at the transmitter in such manner that they may be readily separated at the receiver without impairing the effectiveness of either signal.

These and other objects and features of the invention will be more fully understood as the description proceeds.

In the drawings:

Fig. 1 illustrates a frame having two areas of different light intensities;

Fig. 2 illustrates a video signal which might be obtained by scanning a horizontal line of said area;

Fig. 3 illustrates another frame having two areas of different brighter light intensities;

Fig. 4 illustrates a video signal which might be obtained by scanning a horizontal line of the area of Fig. 3;

Fig. 5 represents a typical video signal which might occur in a television system;

Fig. 6 represents a timing wave for establishing synchronization in the system, a high frequency signal being used for synchronization in one direction and a similar low frequency signal for synchronization in the other direction;

Fig. 7 illustrates the composite signal produced as a result of combining the video signal of Fig. 5 with synchronizing signals derived from signals similar to that of Fig. 6;

Fig. 8 illustrates a carrier wave modulated by the composite signal of Fig. 7;

Fig. 9 is a diagrammatic illustration of a system in accordance with this invention showing the various wave forms produced therein;

Fig. 10 illustrates the vertical synchronizing pulse formed by a portion of the system of Fig. 9;

Fig. 11 is a schematic wiring diagram of a tuned amplifier employed in the system;

Fig. 12 is a similar illustration of a signal-shaping circuit employed in the system;

Fig. 13 is a similar view of a signal amplitude-limiting amplifier employed in the system;

Fig. 14 is a similar illustration of a signal-adding amplifier employed in the system;

Fig. 15 is a similar illustration of a signal-combining amplifier employed in the system; and

Figs. 16 to 18 illustrate the component signals after separation thereof at the receiving station.

In order to enable a better understanding of the invention and the several features thereof, a brief preliminary description will now be given and certain terms will be defined. In a visual image transmission system, the synchronizing signals which are employed usually consist of pulses of brief duration which are advantageously seldom longer than a small percentage of the time interval between the pulses. For the duration of the synchronizing pulses, the video or picture signal should preferably be eliminated. Consequently, it is desirable to make the synchronizing pulses as short as possible and there should be provided means whereby the video signal may be eliminated during each synchronizing pulse. This elimination is known as "blanking" and is accomplished by means of a "blanking" signal which also consists of periodic pulses. For the sake of simplicity and in conformity with the conception and terminology employed by those working in the art, the synchronizing and blanking pulses may be considered to constitute entirely the signals which they comprise, and the portions of each of these signal waves during which no pulse is transmitted may be considered as zero reference lines, even though there may be some biasing voltage present due to the particular apparatus employed. Therefore, in the following description, unless otherwise indicated, the words "signal," "pulses," or "impulses" will be used to indicate only that portion of the signal voltage which departs from the reference voltage.

It is characteristic of the video or picture signal that, except for the periodically blanked portion, the signal is not periodic and contains a unidirectional or zero-frequency component. This signal, as is well known, represents the picture being transmitted and varies in accordance with the brightness of each picture element being scanned. Consequently, in order to obtain the same relative measure of brightness in the reproduced picture at the receiver as that of the picture at the transmitter which is being transmitted, some form of brightness control must be provided.

Referring now to Figs. 1 to 4, in which Fig. 1 represents an area one-half of which is black and one-half gray and Fig. 2 represents the video signal which might be obtained by scanning a horizontal line of the area of Fig. 1, it will be noted that the signal is zero for the portion corresponding to the black portion and has some value V_1 corresponding to the gray portion. Likewise the video signal shown in Fig. 4, which would be obtained by scanning a horizontal line of the gray and white area of Fig. 3, would have a value V_1 representing the gray portion and a value V_2 corresponding to the white portion. The whole frame or picture would be obtained by scanning one line, then a line adjacent the first line etc., according to some regular order. The video signal for the frame would consist of a number of cycles, one for each line, similar to those of Figs. 2 or 4. As far as A. C. components are concerned, the two signals are identical. The difference in illumination between the two is brought out by the zero-frequency component. It will be noted that in Fig. 2 this zero-frequency component would have a value equal to E_1 whereas in Fig. 4 it would have a value of E_2, these values corresponding to the average intensity of illumination of the whole area, and average voltage of the corresponding signal. For the case of moving objects, the average illumination will change at a rate depending upon the rate at which the differently illuminated objects appear and disappear from the picture. Consequently, the signal proportional to the average illumination, which has been defined to be the zero-frequency component, will have an amplitude which varies slowly as the average illumination of the picture changes. In other words strictly speaking, this "brightness" signal or zero-frequency component is not an absolute zero-frequency signal but includes A. C. compounds of very low frequency compared with other frequencies of the video signal. The reference level for the said zero-frequency or brightness component may be taken to be the level corresponding to zero illumination.

It would be well at this point to distinguish between "brightness" and "contrast." As shown above, "brightness" may be considered as the measure of the average illumination of the picture or image. On the other hand, "contrast" may be defined as the difference in illumination between two points on the picture or image. It will be seen, therefore, that while the A. C. components of the video or picture signal may well represent and define contrast in a picture, they will not necessarily represent and control brightness accurately unless some method or means, such as the transmission of a signal to establish the reference level, is used. The present invention provides a method and means by which automatic brightness control may be maintained by establishing a fixed transmittable reference level or plurality of levels in the composite signal produced, and by so arranging and maintaining the video signal with respect to at least one of these levels that the zero-frequency or brightness control component is included therein.

Furthermore, the invention provides a method and means whereby the synchronizing signals are maintained at constant amplitude with respect to the reference axis, so that these signals may be separated by amplitude and wave shape discrimination, which is very desirable.

In a conventional television system, good definition requires that each frame be subdivided into a large number of lines which are scanned successively by the scanning apparatus. The scanning may be of simple form in which the successive lines follow directly one after another, or it may take the form of interlaced scanning in which successive sets of lines are scanned to form the complete frame, the sets of lines being interlaced or intermingled. If the scanning beam moves horizontally, as is conventional practice, the horizontal scanning frequency will be considerably higher than the vertical scanning frequency. For good definition, simple interlaced scanning may be employed, in which two interlaced sets of lines constitute a frame. There may be 345 lines to a frame and 30 frames per second. This would require for interlacing a vertical scanning signal of 60 pulses per second and a horizontal scanning signal of 10,350 pulses per second. Under these circumstances, the time required to scan one line and return would be about 97 micro-seconds and the synchronizing impulse which actuates the means causing this deflection might require about 7 micro-seconds. The time duration of the vertical synchronizing pulse might be approximately 500 micro-seconds.

It has been found desirable at the receiver to distinguish between the horizontal and vertical synchronizing signals by discriminating between them by both signal amplitude and wave shape.

Thus, the horizontal synchronizing signal may consist of high, relatively steep-sided pulses, which would include only high frequency components, whereas the vertical synchronizing signal might consist of relatively low, gently sloping pulses, which would include only low frequency components. Since frequencies above a certain limit may not be transmitted, the steepness of the horizontal pulses would be limited by this feature, and the pulses would resemble inverted truncated V's. Heretofore, the two signals have been simply added together, but since several horizontal signal pulses, which may be separated from the vertical by amplitude relation and which are of longer duration at the bottom than the top, will occur during each vertical signal pulse, the two will coact detrimentally to the efficacy of the system unless certain precautions are observed. The present invention provides means by which this detrimental coaction of the two signals is prevented and the performance of the system is improved. The invention includes means for combining the two synchronizing signals so that the top of the horizontal pulses and the general shape and amplitude of the vertical pulse are not disturbed.

In accordance with the invention, there is provided means whereby valleys or serrations may be cut or formed in the vertical synchronizing pulse and arranged so that the horizontal synchronizing pulse may be fitted into them in interdentate fashion. In the case of simple scanning the valleys or serrations cut in the vertical synchronizing pulse may be arranged so that the horizontal synchronizing pulses may be placed in them, the period of the serrations being the same as the period of the horizontal synchronizing signals and the duration of the serrations slightly greater than that of the horizontal synchronizing pulses. In the case of simple interlacing, the vertical scanning pulses will be spaced apart at intervals corresponding to an integral number plus one-half the horizontal pulse intervals. Consequently, as the valleys must be arranged in exact timed relation with the horizontal synchronizing pulses, the interval between the centers of the valleys must be one-half the interval between horizontal synchronizing pulses. By this invention, there is provided simple electrical means adapted to produce such a serrated vertical synchronizing pulse which is accurately formed and properly timed with respect to the horizontal and vertical scanning systems of the transmitter. The same result might be obtained by modifying the horizontal synchronizing pulses in accordance with the vertical synchronizing pulse, or in other words, by cutting off the bottom of the horizontal pulses.

Referring now particularly to Figs. 5 to 8, in Fig. 5, there is illustrated a typical video or picture signal. The brightness or intensity of illumination of the picture is proportional to the voltage of the signal with respect to the reference or zero axis. Consequently, the average brightness is proportional to the zero-frequency component. In Fig. 6, there is illustrated a typical signal obtained from either the horizontal or vertical scanning means at the transmitter, which signal may be used to form the synchronizing signal. It may consist of short rectangular pulses occurring periodically at a frequency which may be of the order of 10 kilocycles per second for the horizontal scanning, or of the order of 60 cycles for vertical scanning. It will be understood that pulses of other wave shape may be used.

Fig. 7 illustrates the composite signal formed in accordance with the invention by combining the video and synchronizing signals after modification thereof in the manner hereinafter set forth. This composite signal may be used to modulate a carrier wave to obtain a modulated wave such as shown in Fig. 8.

Referring particularly to Fig. 7, it will be noted that a reference level A—B is established and the portion of the composite signal above this level represents the combined synchronizing signals, while the portion of the composite signal below the reference level represents the video signal. The horizontal synchronizing signal is shown at 1 and the vertical synchronizing signal is shown at 2. The video signal is designated 3, while the intervals during which the video signal is blanked or eliminated are shown at 4. The present invention provides a novel method and means for definitely establishing the reference level A—B and likewise for definitely establishing the magnitude of the synchronizing signals above this level. The video signal may be added below this level in such manner that the negative peaks correspond to picture high lights, while zero signal or the values approaching the reference level correspond to deep shadows of the picture. The manner in which the component signals are thus combined will be described fully hereinafter.

Referring now to Fig. 9, there is shown diagrammatically at 5 a conventional camera tube and associated equipment such as is employed at the transmitter of a television system and which functions to generate or produce the video signal, as shown in Fig. 5, and the horizontal and vertical scanning signals, as illustrated in Fig. 6, from which the horizontal and vertical synchronizing signals are derived. The horizontal scanning impulses may be applied to a tuned amplifier 6 which will be described in detail hereinafter. The signal applied to this tuned amplifier is illustrated at 7, while the signal obtained therefrom is shown at 8. It will be noted that the signal 8 is substantially in the form of a sine wave having the excitation frequency. This wave 8 is applied to the shaping circuit 9 which will be fully described later and which functions to cut off all of the wave 8 below a certain value indicated by the dotted line 8a. The phase is reversed in the shaping circuit 9 and the output wave 10 comprises successive short spaced negative pulses. These pulses are applied to an amplitude-limiting amplifier 11 which functions to cut off the peaks of the pulses 10, thus producing corresponding pulses 12 which are reversed in phase and which are substantially rectangular.

The horizontal scanning signal 7 is also applied to a second tuned amplifier 6a which is similar to the tuned amplifier 6 but which is tuned to the second harmonic of the input signal, thus producing a wave such as shown at 13. This wave is applied to a shaping circuit 9a similar to the shaping circuit 9 and which functions to produce negative impulses, as shown at 14, which have the same timing and shape as the portions of the wave 13 above the line 13a. If a twice horizontal frequency signal is available from 5, it may be applied instead of signal 7 to unit 6a.

The vertical scanning signal 15, which is derived from the camera equipment 5, may be ap-

plied to a tuned amplifier 6b similar to the previously mentioned tuned amplifiers but which may be tuned to a higher harmonic of its pulse frequency, for example, the fifth or sixth harmonic. It will be understood, that the representations of the signals are not intended to show frequency relations, as this is obviously impossible. Therefore, the designations H.F. and L.F. are employed to indicate high and low frequency. The amplifier 6b has desired damping characteristics and there is produced, therefore, in the output circuit of the amplifier 6b an oscillatory wave 16 which is damped and which has a frequency corresponding to the frequency of the tuned circuit of the amplifier. It will be understood that the output from amplifier 6b really includes all of the component frequencies of the input signal, as would be shown by a Fourier analysis, but in the wave 16, the harmonic to which the tuned circuit is resonant is accentuated. This damped wave is applied to a shaping circuit 9b which is similar to the previously-mentioned shaping circuits and which functions to cut off all of the wave 16 except the upper part of the first positive peak of each wave train received from the tuned amplifier, that is, all of the wave above the dotted line 16a. The resulting wave takes the form shown at 17. Thus, it will be seen that the pulsating signal 15 has been converted into a pulsating wave consisting of relatively small and narrow pulses and having a large interval between pulses during which the output voltage is constant. As each of these pulses will later become a vertical synchronizing pulse, it is desirable that it should occupy a relatively small interval as compared with the interval between pulses and this interval may be controlled by the harmonic to which the tuned circuit of the amplifier is resonant and by the portion of the first positive swing selected by the shaping circuit 9b.

Each of the tuned amplifier and shaping circuit combinations (i. e. the elements 6 and 9, the elements 6a and 9a, or the elements 6b and 9b) constitutes a device which when energized by a pulse signal of the character disclosed, functions to produce a new pulse signal of specific character as described more particularly hereinafter. Each of these devices may be used in any instance where it may be desired to utilize signals of the character of those produced by the devices.

The output pulse signals from the shaping circuits 9a and 9b are added together to form a combined signal in an adding amplifier 18 which will be described fully hereinafter. It will be noted that the pulses 14 are negative, while the pulses 17 are positive. Furthermore, the amplitude of pulses 14 may be somewhat greater than that of pulses 17. Consequently, the output of the adding amplifier 18 comprises a voltage having negative depressions or valleys, as illustrated at 19, these valleys having a period corresponding to twice the horizontal scanning frequency for interlaced scanning. Thus, in effect, valleys or depressions are cut or formed in the vertical synchronizing pulse whose beds may be negative with respect to the signal level and whose positions correspond accurately in time relation to twice the frequency of the horizontal scanning impulse.

The output of the adding amplifier 18 is applied to a shaping circuit 20 which is similar to the shaping circuits 9 above mentioned and whose function is to pass only positive input voltages and to remove the negative voltages. The output of this circuit will have the form shown at 21 and illustrated more clearly in Fig. 10. Referring for the moment to Fig. 10, it will be noted that the several valleys or depressions in the vertical scanning pulse are accurately and precisely located with respect to the horizontal scanning signals. It will be obvious therefore that the horizontal scanning pulses may be added to the vertical scanning pulse, as will be presently described, and the horizontal scanning impulses may be made to fit properly into their respective places in the vertical scanning pulse by adjusting the tuned circuit LC of the horizontal frequency tuned amplifier 6 which will modify the phase relation between the horizontal synchronizing signal and the serrations in the vertical pulse. The height of the horizontal scanning impulse may conveniently be about twice that of the vertical scanning pulse peak and the duration of the horizontal impulses should be somewhat less than the time represented by the width of the valleys in the vertical scanning pulse. In the case of simple interlaced scanning, one set of horizontal scanning impulses may fall in valleys C, D, E, F, G, while the next set would fall in valleys H, I, J, K. It will be understood that where more complicated forms of interlaced scanning are used, the number of sets of valleys will be increased accordingly.

Referring now again to Fig. 9, the horizontal scanning impulses 12, produced as above described, may be added to the vertical scanning pulse 21 by means of the adding amplifier 22 which may be similar to the adding amplifier 18. The output of the adding amplifier 22 is a composite signal composed of the horizontal and vertical synchronizing signals and taking the form shown at 23 and illustrated more clearly at the right-hand end of Fig. 7. In other words, this composite signal is similar in form to the portion of the signal of Fig. 7 above the reference level A—B.

The apparatus above described which first produces the serrated pulse signal 21 and then combines the pulse signal 12 therewith to form the composite signal 23, may be used in any instance where it may be desired to utilize signals of this character. The elements involved may be constituted as a unit which is adapted to be energized by two signals and functions to produce the composite signal 23.

The damped wave 16 produced by tuned amplifier 6b from the vertical scanning signal is applied also to the shaping circuit 9c which is similar to the shaping circuit 9b but is adapted to pass a larger portion of the first positive swing of the damped wave, that is, the portion above dotted line 16b, thus producing pulses 24 which are similar to pulses 17 but are of somewhat greater duration and of greater amplitude. It will be noted, however, that the pulses 24 are precisely centered with respect to the time of the pulses 17. The pulses 24 may be applied to an amplitude-limiting amplifier 11a, similar to the corresponding amplifier 11, which cuts off the upper portion of each pulse, producing blanking signals or pulses 25 which are precisely determined with respect to the time of the vertical synchronizing pulses 21. It should be noted that the signals 17 and 24 could be produced by passing the signal 16 through a device which would pass only the signal 24 and then passing the signal 24 through a second device which would pass only the signal 17.

The wave 8 produced from the horizontal scanning signal 7 by the tuned amplifier 6 is also applied to a shaping circuit 9*d* which is similar to the shaping circuit 9 but cuts off at 8*b* rather than 8*a* and consequently produces pulses 26 which are somewhat larger than the pulses 10. Pulses 26 may be applied to an amplitude-limiting amplifier 11*b* which, like amplifier 11*a*, functions to cut off the peaks of the pulses 26, producing substantially rectangular pulses 27. It will be understood that the pulses 25 and 27 occur at the respective frequencies of the vertical and horizontal scanning signals and, therefore, the number of pulses 27 per unit time will be much greater than the number of pulses 25. The pulses 25 and 27 are applied to an adding amplifier 22*a*, similar to the adding amplifier 18 and 22, thus producing a composite signal, as shown at 28. This composite blanking signal corresponds to the blanking portions of the signal shown at 4 in Fig. 7. The signal 28 may be used directly in the combining amplifier 31 or it preferably may again be applied to an amplitude-limiting amplifier 11*c*, similar to the corresponding amplifiers above mentioned, which functions to cut-off the upper portion of the signal 28 above the dotted line, thus producing a signal of the form shown at 29.

The video signal produced by the camera tube 5 is preferably passed through a D. C. amplifier 30. A D. C. amplifier is one which will transmit signals of all frequencies from some fixed frequency down to and including zero frequency with substantially uniform gain. The video signal is then applied, together with the composite synchronizing signal 23 and the composite blanking signal 29, to a combining amplifier 31 which will be described in detail later. This amplifier produces the composite signal of Fig. 7. The composite signal may be transmitted alone or it may be used to modulate a carrier wave by means of a conventional modulator.

Referring now to Figs. 11 to 15 there are shown in these figures the various devices employed in the system of Fig. 9. Certain parts of the circuits shown in these figures comprise conventional means well known in the art which require no description. For example, in several instances, conventional resistance-capacitance coupled stages of amplification are used. In certain portions of the circuit of Fig. 9, the polarity of the signal in an amplifier is reversed between input and output. It will be understood, of course, that this phase reversal may be obtained by using the proper number of stages in each amplifier. It is, of course, well known in the art that the output of a single stage amplifier is reversed with respect to the phase of its input.

In Fig. 11, there is illustrated a tuned amplifier which may be employed at 6, 6*a* and 6*b* in the system of Fig. 9. This amplifier may comprise a vacuum tube 32. A variably tuned circuit LC may be provided in the output circuit of the tube 32, which may be tuned to a desired frequency, as above described, and by means of which the output signal may be shifted in phase. A "high Q" amplifier will produce a substantially undamped wave as shown at 8 and 13, whereas a "low Q" amplifier will produce a damped wave as shown at 16.

It will be seen from Fig. 9 that the tube 32 of Fig. 11 is supplied with a pulse signal which occurs at a certain rate. This signal is applied to the control grid of the tube 32 and causes a corresponding variation in the space current of the tube. The resonant circuit LC in the output circuit of the tube is thus subjected to a current which pulsates in accordance with the input signal. Since this circuit is less than critically damped, it oscillates at its natural frequency. If the natural frequency is the same as the rate of occurrence of the pulses, the output of the circuit, that is, the voltage built up across the resonant circuit LC, will comprise a sinusoidal wave having the same frequency as the input signal. If now, the resonant frequency of circuit LC is changed slightly from that of the frequency of the pulse signal, the phase of the output signal may be varied slightly with respect to that of the input signal and the system will continue to produce a sinusoidal output signal. This is the condition indicated in amplifier 6 of Fig. 9.

The resonant circuit LC may also be tuned to a harmonic of the frequency of the pulse signal, in which case the output signal, that is, the voltage across the circuit LC, will again be a substantially sinusoidal signal having a frequency corresponding to the natural period of the circuit LC and therefore, to the harmonic of the input signal. Suppose, for example, that the circuit LC is tuned to the third harmonic of the pulse signal. As the voltage is changed in the input circuit, the current through the output circuit is modified, which causes the resonant circuit to oscillate at its natural frequency, in this case going through three cycles of oscillation at which point it is again energized by the next similar voltage change in the input circuit. At some point of time between these two times, an opposite voltage change will have occurred in the input circuit and this will serve to reenergize the oscillating circuit by excitation in a proper direction at the equivalent time interval. If now, the circuit LC has a high "Q," that is very low series resistance, the oscillations will tend to die out slowly. In other words, the amplitudes of the initial cycle and that of corresponding cycles will not differ by any material amount. If, on the other hand, the circuit has a low "Q," that is high damping or large series resistance, then the oscillations will tend to die out rapidly and there will be a marked difference in amplitude between the initial and succeeding cycles. Such a damped oscillator is shown at 6*b* in Fig. 9.

In Fig. 12, there is illustrated a shaping circuit which may be employed at 9, 9*a*, 9*b*, 9*c*, 9*d* and 20 in Fig. 9. This circuit conveniently may comprise a tube 33 having its grid biased negatively beyond plate current cut-off by the biasing source 34, the value of which determines the portion of the positive cycle being transmitted.

By biasing the grid of tube 33 below the point of plate current cut-off, the tube will not draw any plate current unless the control grid is energized positively by a signal sufficiently large to raise the control grid potential above the cut-off point. Thus the tube 33 serves as an amplitude-controlled selecting system in that of any input signals supplied to the control grid, only that portion of the signal whose instantaneous amplitude is greater than some predetermined amount, will cause any change in the output circuit. For example, referring to Fig. 9, the shaping circuit 9*a* is supplied by an input signal 13, which is applied to the input circuit of a stage such as shown in Fig. 12. The grid of the tube 33 is biased negatively by the battery 34 so that the actual potential on the control grid exceeds the value corresponding to plate current cut-off only when the signal 13 of Fig. 9 is greater than the ampli-

tude level 13a. Thus, the only part of the signal which is transferred through the tube is the part above the level 13a and when amplified, this part appears as the output signal 14. This output signal appears between the anode and ground of the tube 33, as indicated in Fig. 12.

In Fig. 13, there is illustrated an amplitude-limiting amplifier which may be employed at 11, 11a, 11b, and 11c in the system of Fig. 9. This device may comprise an amplifier 35 having a biasing source 36 and a tube 37 coupled thereto as illustrated. The tube 37 has a relatively large resistance 38 in its input circuit. Zero bias is applied to the control grid of this tube 37 and, consequently, when the input signal becomes positive, the grid draws current which will produce a voltage drop in the resistance 38 which will prevent the positive portion of the wave from driving the grid further positive, thereby producing the rectangular signal as above described.

In Fig. 14, there is illustrated an adding amplifier which may be used at 18, 22, and 22a in Fig. 9. This device may comprise a pair of tubes 39 and 40 having a common anode or output circuit. The input or grid circuits of these tubes are separate, consequently interaction between the two signals other than in the output circuit of the device is avoided. In the output circuit the two signals are combined or added together.

Suppose now that an input signal is applied to the tube 39 of Fig. 14. This signal applied to the control grid of the tube causes a variation in the plate current of the tube which causes a variation of the current through the common anode resistor. Likewise, a second signal applied to the input circuit of tube 40 will cause a variation of its plate current, which will likewise cause this signal to appear across the common load or anode resistor, and the resultant signal obtained will be the sum of the signals due to current variations in each tube. It will further be noted that due to the fact that a vacuum tube is inherently a one way relay, the output signal due to tube 40 cannot react back to any appreciable extent through the tube 39 to modify the input signal applied to that tube.

Referring now to Fig. 9, it will be seen that the tuned amplifiers 6a and 6b are energized by pulse signals having a frequency corresponding to the horizontal and vertical synchronizing signal frequencies, respectively; that the tuned amplifier 6a produces a sinusoidal signal having twice the frequency of the horizontal synchronizing signal; and that the shaping circuit 9a transmits only that portion of the thus formed harmonic signal above the level 13a, thus forming an output signal 14. Likewise, the tuned amplifier 6b, which is tuned to a harmonic of the lower synchronizing signal frequency and whose resonant circuit is of the low "Q" type, produces a damped harmonic wave train as illustrated at 16, of which the shaping circuit 9b transmits only that portion of the initial cycle having an amplitude greater than the level 16a, thus forming the signal 17. The signal 14 and the signal 17 are added in an adding amplifier 18 such as shown in Fig. 14 to produce a resultant signal 19, which is then passed through an additional shaping circuit 20, which serves to transmit only that portion of the signal having an amplitude greater than the level indicated by the dotted line, thus forming the resultant signal 21.

In Fig. 15, there is illustrated a combining amplifier which may be employed at 31 in the system of Fig. 9 to produce the desired composite signal. This device may comprise a tube 41 to which the video signal having negative signal polarity may be applied, said signal corresponding to the output signal of a conventional camera tube which likewise is of negative polarity and a tube 42 to which the positive blanking signal may be applied. These tubes have a common output or load circuit including the resistor 43 and they are directly coupled to tube 44. The tube 42 may conveniently be biased to cut-off except when the blanking signal is applied. Under these conditions, the tube 42 will draw no current except during the blanking period and consequently will produce no voltage drop across the resistor 43 except during the blanking period.

The video signal applied to tube 41 will be reversed in phase and will appear across the resistor 43. Consequently this signal will be applied to the input of tube 44. During the period when the blanking signal becomes positive, however, the plate current of tube 42 will produce a voltage drop across the resistor 43 which will bias tube 44 to cutoff. Consequently the output of tube 44 will appear across the resistor 45 in its output circuit in the same phase as the input video signal and perhaps greater in magnitude. During the blanking period, however, tube 44 is biased to cutoff as above stated and, consequently, draws no current and will produce no voltage drop across the resistor 45.

The negative synchronizing signal is applied to a tube 46, the anode of which is directly connected to the anode of tube 44. When negative synchronizing signals are applied to the grid of tube 46, they will decrease the current through this tube and, consequently, will appear as positive signals across the resistor 45.

It will be noted that the reference axis A—B of Fig. 7 is established by the current drain of tubes 44 and 46 during the time interval in which the blanking signal is applied to tube 42 and no synchronizing signal is applied to tube 46. The synchronizing signals will appear in the output across resistance 45 as voltages having a greater magnitude than the reference level, while the video signal including the zero-frequency component will appear as voltages having a lower magnitude than that level.

Referring again to Fig. 7 which represents the composite signal including video, synchronizing, and brightness control signals, it is noted that starting at the left-hand end of the figure the video signal 3 is blanked out for a short duration of time indicated by 4 during which time the horizontal synchronizing signal 1 is inserted above the reference level A—B. The duration of the blanking signal 4 should be slightly greater than that of the horizontal synchronizing pulse 1. The video signal then again appears below the level A—B and is again blanked out at 4 and the next horizontal synchronizing pulse which would correspond to the line immediately following the first-mentioned pulse appears. This is followed by another portion of video signal and then by a pulse 2 corresponding to a vertical synchronizing pulse. For the duration of the vertical synchronizing pulse 2, the video signal is held completely blank. The duration of the serrations in the vertical pulse should be sufficient to permit the insertion of the horizontal synchronizing pulses without interaction.

At the receiver the modulated carrier shown in Fig. 8 whose envelope corresponds to the wave shape of Fig. 7 may be demodulated by a linear rectifier which might pass only that portion of the

signal on one side of the central dot-and-dash line. A signal corresponding to that of Fig. 7 may be obtained from the output of this linear rectifier and by adding a constant voltage to this rectified voltage a signal may be obtained which corresponds to the input signal including the zero-frequency component at the transmitter. As the synchronizing signals are so arranged with respect to the video signal as to decrease the light intensity of the image of the picture tube beyond the no-light-level, this signal may be applied directly to the picture tube. It will be noted that the blanked portions of the video signal are so arranged as to form a black border around the image at the picture tube. Likewise, since the synchronizing signals are fixed with respect to the reference level A—B, which may be established at the receiver with a battery, they may be separated from the video by amplitude-limiting devices, as shown, and then further separated into horizontal and vertical synchronizing signals by a frequency-selective circuit, and further amplitude-selective devices. As may be seen from a consideration of the respective frequencies, the frequency-selective network will remove the high frequency serrations from the low frequency vertical pulses.

The resultant signals which are obtained at the receiver are illustrated in Figs. 16 to 18. Fig. 16 corresponds to the blanked video signal, with the synchronizing signals removed as is preferable. The horizontal blanking supplies the black border on the sides of the picture, while the vertical blanking supplies the black border at the top and bottom of the picture. The blanking also cuts off the electron beam of the picture tube during the beam return time. Figs. 17 and 18 represent respectively the horizontal and vertical synchronizing signals after they have been separated by amplitude and frequency-selective means. The synchronizing signals thus obtained may be used to actuate a device at the receiver, such as that shown in my copending application, Serial No. 25,517, filed June 7, 1935.

Although the invention has been illustrated and described with specific reference to a picture transmission system, it is capable of broader application as above mentioned and is susceptible to modification, as will be apparent to those skilled in the art.

I claim.

1. In an electrical system utilizing pulse signals; a source of pulse signals of one amplitude and having a certain rate of occurrence; a second source of pulse signals having a higher amplitude and a higher rate of occurrence than the pulses of said first pulse signal; means, connected to both of said sources, for combining in opposed relation a signal from one of said sources and a signal from the other of said sources, to form a combined pulse signal; means comprising a shaping circuit for changing the wave shape of the pulses of the combined signal to form a pulse signal having serrations therein; and means for combining said last-named signal with a signal from one of said sources.

2. In an electrical system utilizing pulse signals; a source of pulse signals of one amplitude and having a certain rate of occurrence; a second source of pulse signals having a higher amplitude and a higher rate of occurrence than the pulses of said first pulse signal; means responsive to a signal from one of said sources for deriving another pulse signal therefrom; means for combining in opposed relation said derived pulse signal and a pulse signal from the other of said sources, to form a combined pulse signal; means comprising a shaping circuit for changing the wave shape of the pulses of the combined signal to form a pulse signal having serrations therein; and means for combining said last-named signal with a signal from one of said sources.

3. In an electrical system utilizing pulse signals; a source of pulse signals of one amplitude and having a certain rate of occurrence; a second source of pulse signals having a higher amplitude and a higher rate of occurrence than the pulses of said first pulse signal; adjustable means responsive to a signal from one of said sources for deriving another pulse signal therefrom; means for combining in opposed relation said derived pulse signal and a pulse signal from the other of said sources to form a combined pulse signal; means comprising a shaping circuit for changing the wave shape of the pulses of the combined signal to form a pulse signal having serrations therein; and means for combining said last-named signal with a signal from one of said sources.

4. In an electrical system utilizing pulse signals; a source of pulse signals of one amplitude and having a certain rate of occurrence; a second source of pulse signals having a higher amplitude and a higher rate of occurrence than the pulses of said first pulse signal; means responsive to a signal from one of said sources for deriving therefrom another pulse signal having a different rate of occurrence; means for combining in opposed relation said derived pulse signal and a pulse signal from the other of said sources, to form a combined pulse signal; means comprising a shaping circuit for changing the wave shape of the pulses of the combined signal to form a pulse signal having serrations therein; and means for combining said last-named signal with a signal from one of said sources.

5. In an electrical system utilizing pulse signals; a source of pulse signals of one amplitude and having a certain rate of occurrence; a second source of pulse signals having a higher amplitude and a higher rate of occurrence than the pulses of said first pulse signal; means, connected to both of said sources, for combining in opposed relation a signal from one of said sources and a signal from the other of said sources, to form a combined pulse signal; means for transmitting a portion of the cycle of said combined signal to form a pulse signal having serrations therein; and means for combining said last-named signal with a signal from one of said sources.

6. In an electrical system utilizing pulse signals; a source of pulse signals of one amplitude and having a certain rate of occurrence; a second source of pulse signals having a higher amplitude and a higher rate of occurrence than the pulses of said first pulse signal; means, connected to both of said sources, for combining in opposed relation a signal from one of said sources and a signal from the other of said sources, to form a combined pulse signal; means comprising a shaping circuit for changing the wave shape of the pulses of the combined signal to form a pulse signal having serrations therein; and means for adding said last-named signal to a signal from one of said sources.

7. In an electrical system utilizing pulse signals; a source of pulse signals of one amplitude and having a certain rate of occurrence; a second source of pulse signals having a higher amplitude and a higher rate of occurrence than the pulses of said first pulse signal; means for deriv-

ing a pulse signal from said first-named source; means for deriving a pulse signal from said second-named source, means for combining said derived pulse signals in opposed relation, to form a combined pulse signal; means comprising a shaping circuit for changing the wave shape of the pulses of the combined signal to form a pulse signal having serrations therein; and means for combining said last-named signal with a signal from one of said sources.

8. In an electrical system utilizing pulse signals, a source of an electric pulse signal, said signal including wave components of fundamental and harmonic frequency, one of said components exceeding in magnitude any of the others, means for selecting one of said wave components other than the said largest component from said source, and aperiodic wave shaping means for transmitting only a portion of each cycle of the said selected wave component, whereby a new pulse signal is formed.

9. In an electrical system utilizing pulse signals, a source of an electric pulse signal, said signal including wave components of fundamental and harmonic frequency, one of said components exceeding in magnitude any of the others, means for selecting one of said wave components other than the said largest component from said source, aperiodic wave shaping means for transmitting only a portion of each cycle of the said selected wave component, whereby a new pulse signal is formed, and additional aperiodic wave shaping means for transmitting only a portion of each cycle of said selected wave component, whereby a different new pulse signal is formed.

10. In an electrical system utilizing pulse signals, a source of an electric pulse signal, said signal including wave components of fundamental and harmonic frequency, one of said components exceeding in magnitude any of the others, means for selecting one of said wave components other than the said largest component from said source, and aperiodic wave shaping means for transmitting only a portion of each cycle of the said selected wave component having an instantaneous potential between two amplitude levels one of which is greater than the other, whereby a new pulse signal is formed.

11. In an electrical system utilizing pulse signals, a source of an electric pulse signal, said signal including wave components of fundamental and harmonic frequency, means for selecting one of said harmonic wave components from said source to the exclusion of the fundamental and other harmonic components, and aperiodic wave shaping means for transmitting only a portion of each cycle of the said selected harmonic wave component, whereby a new pulse signal is formed.

12. In an electrical system utilizing pulse signals, a source of an electric pulse signal, said signal including wave components of fundamental and harmonic frequency, means for selecting one of said harmonic wave components from said source, aperiodic wave shaping means for transmitting only a portion of each cycle of the said selected wave which has a positive polarity with respect to one amplitude level and a negative polarity with respect to a second amplitude level greater than said first-named amplitude level, and additional aperiodic wave shaping means for transmitting only a portion of each cycle of the said selected wave which has a certain polarity with respect to a third predetermined amplitude level.

13. In an electrical system utilizing pulse signals, a source of an electric pulse signal, said signal including wave components of fundamental and harmonic frequency, means responsive to said source for producing damped wave trains having a frequency corresponding to one of said harmonic frequencies to the exclusion of the fundamental and other harmonic frequencies, and means for transmitting only a portion of each of said wave trains, whereby a new pulse signal is formed.

14. In an electrical system utilizing pulse signals, a source of an electric pulse signal, said signal including wave components of fundamental and harmonic frequency, means responsive to said source for producing damped wave trains having a frequency corresponding to one of said harmonic frequencies, aperiodic wave shaping means for transmitting only a portion of each of said wave trains which has a positive polarity with respect to one amplitude level and a negative polarity with respect to a second amplitude level greater than said first-named amplitude level, and an additional aperiodic wave shaping means for transmitting only a portion of each of said wave trains which has a certain polarity with respect to a third amplitude level.

15. In an electrical system utilizing pulse signals; an output circuit; means responsive to an input signal for producing in said output circuit an output signal having the same wave shape as said input signal and having one polarity with respect to a predetermined output potential level; means for eliminating said output signal and establishing said predetermined level in said output circuit at intermittent intervals; and means responsive to another input signal for producing in said output circuit, during said intervals, an output signal having the same wave shape as said other input signal and having the opposite polarity with respect to said predetermined level.

16. In an electrical system utilizing pulse signals; an output circuit; means responsive to an input signal for producing in said output circuit an output signal having the same wave shape as said input signal and having one polarity with respect to a predetermined output level; means responsive to a second input signal for eliminating said output signal and establishing said predetermined level in said output circuit at intermittent intervals; and means responsive to a third input signal for producing in said output circuit, during said intervals, an output signal having the same wave shape as said third input signal and having the opposite polarity with respect to said predetermined level.

17. In an electrical system utilizing pulse signals; an output circuit; means responsive to an input signal for producing in said output circuit an output signal having the same wave shape as said input signal and having one polarity with respect to a predetermined output level; means responsive to a second input signal for eliminating said output signal and establishing said predetermined level in said output circuit at intermittent intervals; a source of input signals; means responsive to said source of input signals for producing in said output circuit, during said intervals, an output signal having the same wave shape as the input signals from said source and having the opposite polarity with respect to said predetermined level; and means responsive to said source of input signals for deriving said second signal.

18. In an electrical system utilizing pulse signals; an output circuit; means responsive to an

input signal for producing in said output circuit an output signal having the same wave shape as said input signal and having one polarity with respect to a predetermined output level; means responsive to a second input signal for eliminating said output signal and establishing said predetermined level in said output circuit at intermittent intervals; a source of input signals; means responsive to said source of input signals for producing in said output circuit, during said intervals and of lesser duration than the duration of said intervals, an output signal of one amplitude having the same wave shape as the input signals from said source and having the opposite polarity with respect to said predetermined level; and means responsive to said source of input signals for deriving said second signal.

19. The method of forming narrow pulses occurring at a desired frequency from a pulse signal having wave components of different frequencies including the desired frequency, which comprises selecting from said pulse signal the wave component having the desired frequency, forming a wave signal having a frequency corresponding to the desired frequency, and transmitting only a portion of said wave signal to form narrow pulses occurring at the desired frequency.

20. The method of forming accurately timed narrow pulses from a pulse signal having wave components of fundamental and harmonic frequency, which comprises selecting one only of the harmonic wave components from said pulse signal, forming a wave signal having a frequency corresponding to the selected harmonic frequency, and transmitting only a portion of said wave signal to form narrow pulses occurring at the selected harmonic frequency.

21. The method of forming accurately timed narrow pulses from a pulse signal having wave components of fundamental and harmonic frequency, which comprises selecting one only of the harmonic wave components from said pulse signal, forming damped wave trains having a frequency corresponding to the selected harmonic frequency, and transmitting only a portion of each of said damped wave trains to form narrow pulses occurring at the selected harmonic frequency.

22. In combination, an electron tube to which pulse signals having different frequency components are supplied, an anode circuit for said tube, a resonant circuit connected in the said anode circuit, whereby the output of said tube is a wave signal whose frequency is determined by said resonant circuit, and means connected to said anode circuit for producing pulses occurring at the frequency of said wave signal.

23. In combination, an electron tube to which pulse signals having different frequency components are supplied, an anode circuit for said tube, a resonant circuit connected in the said anode circuit, whereby the output of said tube is a wave signal whose frequency is determined by said resonant circuit, and amplitude-limiting means connected to said anode circuit for producing pulses occurring at the frequency of said wave signal.

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